Esophageal perforation during left atrial radiofrequency ablation: Is the risk too high?

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Objective: Intraoperative radiofrequency ablation of atrial fibrillation (IRAAF) is a recently developed procedure being performed in an increasing number of patients. We have performed left atrial IRAAF in 387 patients since August 1998. The purpose of this article is to describe a serious complication of this procedure, namely IRAAF-induced esophageal perforation, in detail to identify possible risk factors.

Methods: Left atrial IRAAF was performed with a commercially available unipolar probe as an isolated procedure (n = 129) or in combination with mitral valve surgery (n = 163) or other surgical procedures (n = 95). Operations were performed either through a conventional sternotomy or right minithoracotomy.

Results: Four (1%) patients had esophageal perforation after radiofrequency ablation. All 4 patients presented after an initially unremarkable postoperative course, with sudden neurologic symptoms from esophagoatrial air embolization occurring in 3 of the patients. Three patients were successfully treated with extensive esophageal resection, and one died from massive air embolism. All perforations occurred in patients undergoing minimally invasive IRAAF. Comparison with other patients undergoing isolated minimally invasive IRAAF (n = 129) failed to reveal any reliable predictors of esophageal injury, including patient body size, operating times, or radiofrequency biophysical parameters.

Conclusions: Left atrial IRAAF is associated with a small but definite risk of esophageal perforation. Unfortunately, we were unable to identify any risk factors for this life-threatening complication. A high degree of vigilance must be maintained for esophageal injury after IRAAF, particularly in patients with new neurologic deficits. Until safer methods of ablation are developed, we currently recommend against the use of IRAAF in patients undergoing cardiac surgery.

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Chronic atrial fibrillation is a common clinical problem, affecting approximately 10% of the general population older than 75 years. Numerous therapeutic modalities have been developed to treat atrial fibrillation, including several surgical techniques. Intraoperative radiofrequency ablation of atrial fibrillation (IRAAF) as an isolated or combined procedure is an operation that was recently developed to address this common clinical entity. IRAAF involves creation of a series of thermally induced transmural lesions to interrupt the circuits required to propagate atrial fibrillation. It can be successfully applied solely to the left atrium because the ectopic electrical foci and re-entrant circuits are usually anchored here.[1]

TABLE 1. Preoperative characteristics of patients undergoing minimally invasive IRAAF

Variable	Patients without esophageal perforation (n = 129)	Patients with esophageal perforation (n = 4)
Male sex	100 (78%)	3 (75%)
Age (y)	53.0 ± 9.1 (29-70)	54.1 ± 18.9 (36-62)
BSA (m^2)	1.7 ± 0.1 (1.4-2.0)	1.7 ± 0.2 (1.6-1.8)
Weight (kg)	77 ± 10 (50-98)	73 ± 18 (62-87)
Hypertension	20 (16%)	1 (25%)
Nonsignificant CAD	8 (6%)	0 (0%)
Nonsignificant MR	13 (10%)	0 (0%)
PFO/ASD	3 (2%)	1 (25%)

Continuous variables expressed as means ± SD and range. *BSA*, Body surface area; *CAD*, coronary artery disease; *MR*, mitral regurgitation; *PFO*, patent foramen ovale; *ASD*, atrial septal defect.

Several investigators have described encouraging results with intraoperative radiofrequency ablation of the left atrium, achieving curative rates of approximately 80%.[2-4] Electrophysiologists have also successfully performed radiofrequency ablation for atrial fibrillation with percutaneous catheter–based techniques.[5]

We have previously reported on our experience with IRAAF,[4,6-8] and the current study includes a total of 387 patients treated in this manner. The focus of this report, however, is on a particularly serious complication that we have observed in 4 of these patients (ie, radiofrequency-induced esophageal perforation). Recently, Gillinov and coworkers[9] described a single case of esophageal perforation after intraoperative left atrial radiofrequency ablation. Because we have now observed 4 of these same complications, we wanted to gain insight into the mechanisms of this potentially life-threatening injury. Therefore the purpose of this article was to describe these 4 patients in detail and to discuss whether the risks of esophageal injury are prohibitively high for this procedure. Our findings might have significant implications for both surgical and catheter-based radiofrequency atrial ablation procedures.

Methods

IRAAF was performed in 387 patients in our institution between August 1998 and December 2001. Radiofrequency ablation was performed as an isolated procedure in 129 (33%) patients, in combination with mitral valve surgery in 163 (42%) patients, and in combination with other surgical procedures, such as aortic valve surgery, coronary bypass, or atrial septal defect closure, in 95 (25%) patients. Minimally invasive surgical techniques (small right lateral thoracotomy with femoral access cardiopulmonary bypass) were used in 246 (63%) patients, and conventional median sternotomy was performed in 141 (37%) patients.

Patient Characteristics

Four (1%) of 387 patients had perforation of the esophagus. These 4 patients all underwent IRAAF by using minimally invasive techniques. We therefore focused our analysis on patients undergoing minimally invasive isolated IRAAF (n = 133). The preoperative characteristics of these patients are presented in Table 1.

The first patient who had esophageal perforation after IRAAF (hereafter known as patient 1) was a 42-year-old man with a 5-year history of paroxysmal atrial fibrillation unresponsive to several antiarrhythmic agents (propafenone, sotalol, and amiodarone). In the previous 2 years, the frequency and duration of atrial fibrillation episodes progressively increased, occurring at least 4 times per week and lasting 2 to 12 hours in duration. Percutaneous focal ablation of pulmonary vein foci was attempted in this patient but was unsuccessful. The patient had no organic heart disease (normal coronary arteries, left ventricular ejection fraction of 68%), and the left atrium was not enlarged (39 mm).

Patient 2 was a 62-year-old woman with a secundum atrial septal defect and chronic permanent (ie, unresponsive to cardioversion) atrial fibrillation. One year before the operation, the patient had progressive dyspnea and underwent cardiac catheterization. An atrial septal defect was diagnosed, with a left-to-right shunt of 1.5 to 1. Coronary angiography and left ventricular function was normal (ejection fraction of 60%). The left atrium was significantly enlarged (53 mm).

Patient 3 was a 59-year-old man with a 10-year history of atrial fibrillation that was permanent for the last 3 years. Four different antiarrhythmic agents had proven ineffective (flecainide, propafonone, amiodarone, and sotalol), and several electrical cardioversions resulted in relapse to atrial fibrillation within weeks. The patient had no organic heart disease (normal coronary arteries, ejection fraction of 62%), and the left atrium was moderately enlarged (44 mm).

Patient 4 was a 36-year-old man with paroxysmal atrial fibrillation. The patient was highly symptomatic during his episodes of atrial fibrillation, which would last 6 to 36 hours. Antiarrhythmic drug treatment with flecainide was not effective. Treatment with amiodarone was recommended to the patient; however, he did not want long-term medical therapy and preferred curative surgical treatment. The patient had no organic heart disease, ejection fraction was 68%, and the left atrium measured 42 mm in diameter. The patient had undergone partial gastric resection because of recurrent bleeding gastric ulcers several years prior.

Surgical Procedure and Radiofrequency Ablation

Details of the surgical procedure have been reported elsewhere.[4,6-8] In patients undergoing minimally invasive IRAAF, a right lateral minithoracotomy (4-6 cm) was performed in the fourth intercostal

TABLE 2. Intraoperative data of patients undergoing minimally invasive IRAAF

Variable	Patients without esophageal perforation (n = 129)	Patients with esophageal perforation (n = 4)	Patient 1	Patient 2	Patient 3	Patient 4
CPB time (min)	99 ± 31 (43-197)	116 ± 10	128	123	106	110
Aortic XCL time (min)	51 ± 20 (13-127)	62 ± 6	60	63	56	69
OR time (min)	142 ± 36 (88-255)	176 ± 24	170	212	165	160

Continuous variables expressed as means ± SD and range. *CPB*, Cardiopulmonary bypass; *XCL*, crossclamp time; *OR*, operating room.

TABLE 3. Biophysical parameters of the radiofrequency ablation procedure in patients with and without postoperative esophageal perforation

Variable	Patients without esophageal perforation (n = 129)	Patients with esophageal perforation (n = 4)	Patient 1	Patient 2	Patient 3	Patient 4
Total ablation time (min)	15.0 ± 4.0 (9.8-26.4)	16.1 ± 5.3	9.75	17.1	22.5	15.0
Maximum temperature (°C)	84.3 ± 9.3 (75.5-99.2)	91.6 ± 6.9	95.3	83.2	89.1	98.8
Total energy (W/sec)	20,446 ± 30,130 (6900-276,742)	26,540 ± 9029	14,922	34,148	33,218	23,872

Continuous variables expressed as means ± SD and range.

space, and cardiopulmonary bypass was established through femoro-femoral cannulation. Direct aortic clamping was performed with a transthoracic clamp (Chitwood Clamp; Scanlan, Minnesota, Minn) inserted percutaneously in the second intercostal space. The left atrium was incised parallel to the mitral annulus close to the interatrial groove.

Radiofrequency energy was applied with a specially designed hand-held probe with a 10-mm T-shaped electrode tip (Radios 504; Osypka GmbH, Grenzach-Wyhlen, Germany).[6] The electrode tip contained a thermistor for temperature-controlled energy application. Radiofrequency ablation was performed in a unipolar mode between the tip and an external backplate electrode. Power, impedance, and catheter tip temperature were continuously monitored and recorded. On the basis of the results of experimental studies, the preselected target catheter-tip temperature was 60°C, and the duration of energy application was 20 seconds after the target temperature had been achieved.[10] A continuous lesion line was created extending from the inferior aspect of the mitral annulus (P3) to the left lower pulmonary vein. Separate lesion lines were created between the left upper and lower pulmonary vein orifices, between the left and right upper pulmonary vein orifices, and between the right upper and lower pulmonary vein orifices.[11,12] The number of radiofrequency applications required to complete these lines depended on the size of the left atrium. Care was taken not to extend the lesions into the pulmonary veins. After radiofrequency application, the left atrial incision was closed, and the patients were weaned from cardiopulmonary bypass in the usual manner.

Statistical Analysis

Results are given as means ± SD for continuous variables and as percentages for categoric variables. Data were compared between groups by using χ^2 or Fisher exact tests for categoric data and unpaired *t* tests for continuous variables. All statistical analyses were performed with SASS 9.0 software (SASS Inc, Chicago, Ill). Postoperative outcomes were defined according to the guidelines for reporting morbidity and mortality after cardiac valvular operations.[13]

Results

Surgical Intervention and Intraoperative Ablation

The total operation, cardiopulmonary bypass, and aortic crossclamp times of all patients undergoing isolated minimally invasive IRAAF are presented in Table 2. Although the operative times appeared slightly longer for patients who underwent esophageal injury compared with patients without this complication, none of the differences reached statistical significance. Review of the operative notes also failed to reveal any noteworthy intraoperative findings or events in the patients who had esophageal perforation.

Table 3 presents the radiofrequency ablation biophysical parameters, as recorded intraoperatively. There were no statistically significant differences for any of the parameters shown, although mean maximum temperature and total energy appeared slightly higher in the esophageal injury group. In addition, there were no significant differences for any of the parameters shown between patients undergoing minimally invasive surgery (n = 246) versus those who received a conventional median sternotomy (n = 141).

Postoperative Course

All 4 patients with esophageal injury were in stable sinus rhythm immediately after IRAAF. The early postoperative course was unremarkable for all 4 patients, and they were discharged from the intensive care unit within 2 days.

Patient 1 had a fever and increased white blood cell count on the third postoperative day. He underwent multiple investigations, including echocardiography and computed tomography (CT) of the chest, without any abnormalities detected. Empiric antibiotic therapy was instituted, and the fever and leukocytosis abated. On postoperative day 10, the patient had symptoms suggestive of a transient ischemic attack after food intake. His neurologic symptoms completely resolved within 3 hours, but on the following day, more severe postprandial neurologic symptoms occurred. It was postulated that the patient was embolizing air into the left atrium during swallowing, and it was therefore decided to perform an exploratory thoracotomy. After median sternotomy, the left atrium was exposed, and a fistula was detected between the left atrium and esophagus. Portions of the left atrial free wall were obviously hemorrhagic and necrotic. The patient was placed on cardiopulmonary bypass, and the necrotic atrium was excised and replaced with a bovine pericardial patch. The esophagus showed severe necrosis and destruction at its contact site with the left atrium. The necrotic portions of the esophagus were resected, the proximal and distal esophageal stumps were closed, and a feeding gastrostomy tube was inserted. Four days later, the patient had a pneumomediastinum. The patient underwent a posterolateral thoracotomy, and a new fistula was detected between the proximal esophageal stump and the right main bronchus. The proximal esophagus was resected, and a right pneumonectomy was performed. The patient underwent uneventful gastroesophageal reconstruction 6 weeks later.

The postoperative course for patient 2 was uneventful until hematemesis developed 6 days after IRAAF. A tentative diagnosis of upper gastrointestinal bleeding was made, and a gastroscopy was performed. Unfortunately, the gastroscopy procedure was complicated by severe multiorgan air embolism, and the patient died 4 hours later. Pathologic examination revealed subacute esophageal injury and a fistula to the left atrium.

In patient 3 the early postoperative course was completely uneventful, and he was discharged to a cardiac rehabilitation center 9 days after the operation. On postoperative day 12, the patient had fever and neurologic symptoms, and he was referred back to our hospital. A CT scan of the chest with water-soluble contrast revealed evidence of esophageal injury, including contrast medium and free air in the mediastinum between the esophagus and left atrium (Figure 1). A posterolateral thoractomy was performed, and the necrotic esophagus was resected. However, as in patient 1, the patient had signs of a new esophageal perforation 6 days later, and therefore a more extensive esophageal resection was performed. Pathologic examination of the resected esophagus showed typical signs of thermal injury (Figure 2). Four weeks later, the patient underwent successful gastroesophageal reconstruction.

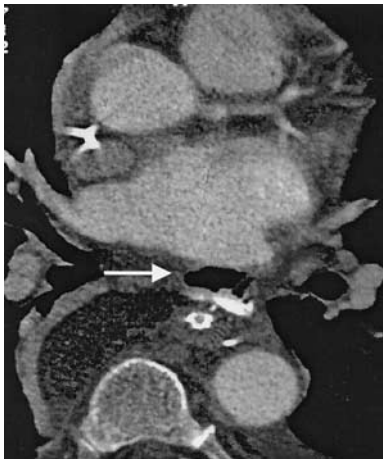

Figure 1. CT scan of the chest after administration of water-soluble contrast, confirming the suspected esophageal injury. The *white arrow* shows free air in the mediastinum.

The early postoperative course for patient 4 was also unremarkable, and he was discharged in sinus rhythm 8 days after IRAAF. On day 11, he complained of severe chest pain and was admitted to an outside hospital. A tentative diagnosis of aortic dissection was made, but a CT scan failed to show any evidence of dissection. Free air was thought to be present in the mediastinum, and the patient was transferred to our hospital. Repeat CT with water-soluble contrast clearly showed evidence of esophageal perforation. The patient underwent successful resection of the esophagus, followed by surgical reconstruction several weeks later.

Discussion

IRAAF through induction of left atrial lesion lines was introduced in 1997.[2,3,6] Because of our initial successes with IRAAF in patients undergoing combined procedures,[14] we started to perform it as an isolated procedure by using minimally invasive techniques in 1998. To the best of our knowledge, the current study represents the largest reported patient cohort treated with IRAAF thus far. As with many novel treatment strategies, new types of complications might appear as more experience is gained. We believe it is important to communicate these new complications to the medical community so that other investigators monitor for their development in their own patient populations and try to develop methods of preventing their occurrence.[15] This might be of particular importance for IRAAF because a rapidly increasing number of institutions have started to perform this procedure worldwide. Furthermore, our report might also affect the practice of percutaneous catheter–based radiofrequency ablation, a procedure that is being

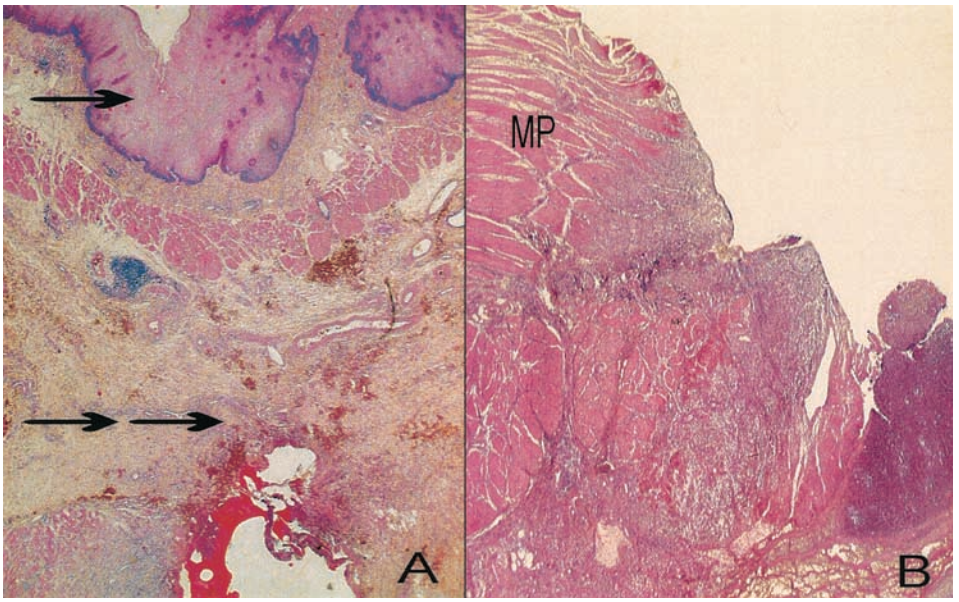

Figure 2. Low- and high-power view of esophageal injury after radiofrequency ablation for atrial fibrillation. (Hematoxylin and eosin; original magnification: A, 25×; B, 100×.) A, Intact squamous epithelium, lamina propria, and muscularis mucosa *(arrow)*. Note the injury of the submucosa and muscularis propria *(double arrow)* with subsequent fibrinous necrosis, hemorrhage, and perifocal inflammatory cell aggregates. B, Muscularis propria with fibrinous necrosis, leading to complete loss of structure (perforation) of the distal esophagus. Massive hemorrhage and neutrophil infiltration are shown.

performed by interventional electrophysiologists in rapidly increasing numbers.[1,5]

Esophageal perforation occurred in 4 (1%) of 387 patients in the current study and was first reported by our group as a possible complication of IRAAF in 2002.[4] When the first esophageal injury occurred, we believed it was secondary to transesophageal echocardiography, a well-described but rare complication of this procedure.[16] We therefore stopped performing transesophageal echocardiography intraoperatively or in the immediate postoperative period in patients undergoing IRAAF. Because we were unsure of the exact mode of injury, however, we also modified the IRAAF procedure by moving the lesion line between the upper pulmonary veins to a more superior location in the left atrium. No esophageal injury was observed in the subsequent 110 patients. The second and third esophageal complications of our series occurred in the same week (IRAAF procedure numbers 154 and 158). Pathologic microscopic evaluation of the resected esophagus supplied evidence for direct thermal injury of the tissue. To avoid this complication in future procedures, we started placing a dry surgical sponge into the oblique sinus between the posterior left atrial wall and the esophagus. No esophageal injury was subsequently observed in the next 121 patients. However, a fourth esophageal perforation occurred in IRAAF patient 381. It should be noted that this fourth patient had undergone prior partial gastric resection for bleeding ulcers and therefore might have had an unusual anatomic position of the esophagus.

We were unable to detect any significant differences between patients with and without esophageal injury, including preoperative (Table 1) and intraoperative (Tables 2 and 3) variables. In the case report by Gillinov and coworkers,[9] the authors concluded that the extremely small body size of their patient partially contributed to the IRAAF-induced esophageal perforation. However, we did not find any differences in patient weight or body mass index between groups. Although mean IRAAF probe temperatures and total energy levels might have been slightly higher in patients with esophageal complications (Table 3), they were within the range of patients without esophageal injury. We were also unable to identify any noteworthy findings in the operative notes of patients who subsequently had esophageal complications. It is possible that differences in the distance between the esophagus and posterior left atrium might have contributed on the occurrence of esophageal injury, but we did not measure this variable. Furthermore, such measurements are difficult to obtain and might therefore have limited clinical utility. Although the number of patients with esophageal perforation in the current study was small, it is troubling that we were unable to identify any reliable predictors of this life-threatening injury.

Histologic studies obtained in patients 3 and 4 revealed that the mechanism of esophageal injury was thermal in

nature. It has been previously shown that intestinal tissue is far more susceptible to radiofrequency-induced thermal injury than muscle tissue.[17] Convection of heat generated at the interface between the ablation probe and left atrial tissue presumably resulted in a significant temperature increase and subsequent damage of adjacent esophageal tissue. This might explain why esophageal injury occurred even though the esophagus was not in direct contact with the ablation probe. Each patient with esophageal injury presented several days after IRAAF, after an initially unremarkable postoperative course, suggesting that the perforation did not occur acutely in the operating room. It is likely that intraoperative thermal damage induced an inflammatory reaction that subsequently led to secondary perforation several days thereafter.

Our experiences with esophageal injury after IRAAF have led to some important conclusions regarding diagnosis and therapy for this particular complication. All 4 patients in our series had moderately increased temperatures, white blood cell counts, and C-reactive protein levels after IRAAF, but unfortunately, these are nonspecific postoperative findings. In patients 1 and 3 the first clinical sign of esophageal perforation was a sudden neurologic deficit similar to a transient ischemic attack. Cranial CT shortly thereafter did not reveal any abnormalities, probably because small cerebral air emboli are usually not detectable by means of CT. The first clinical sign of perforation in patient 2 was hematemesis, leading to a diagnostic gastroscopy being performed for suspected gastrointestinal bleeding. Unfortunately, CO_2 insufflation during the procedure led to massive embolization, resulting in severe neurologic injury and death. Our experiences have led us to recommend that a high degree of suspicion for esophageal injury be present after IRAAF, particularly in patients who have any neurologic signs or symptoms. We also strongly recommend that the first diagnostic procedure be CT of the chest or gastrografin swallow, and gastroscopy should be strictly avoided. Indeed, any diagnostic procedure carrying a risk of air insufflation into the esophagus should be avoided in these patients. When the diagnosis of esophageal perforation has been confirmed, we recommend immediate surgical treatment with wide resection of the affected portion of the esophagus, followed by gastroesophageal reconstruction several weeks later.

Post-IRAAF Esophageal Injury: A "Leipzig Problem"?

It might be speculated that the esophageal complications reported in our series are due to the minimally invasive surgical approach, the specific ablation equipment, or the preselected ablation parameters chosen by our center. However, the same complication was observed by Gillinov and colleagues[9] by using a conventional surgical approach and different radiofrequency ablation equipment (Cobra RF; Boston Scientific, Boston, Mass). These authors also used a different pattern of left atrial lesion lines. In addition, personal communications with surgeons from other centers have revealed at least 4 other post-IRAAF esophageal perforations that have occurred in Germany alone. All 4 of these patients underwent operations through a median sternotomy, and ablation was performed with different radiofrequency systems, including one case that occurred after ablation with a microwave system. Three of the 4 patients subsequently died. We also know of at least one patient who died of sudden massive stroke 1 week after IRAAF. Esophageal perforation might have been the causative factor in this patient and should always be suspected in patients who have sudden neurologic deficits after IRAAF.

Conclusions

We conclude that IRAAF carries a small but significant risk of esophageal injury, a life-threatening complication. Unfortunately, we were unable to identify any preoperative or intraoperative predictors for this dreaded complication. Post-IRAAF esophageal perforation can occur with different surgical approaches and different ablation equipment. A high degree of suspicion must be maintained for signs of esophageal injury after IRAAF, particularly in patients who have sudden neurologic deficits. Gastroscopy must be avoided in such patients.

Although intraoperative ablation has proven to be highly effective in curing patients from atrial fibrillation, we believe the risk of esophageal injury is too high and have therefore stopped performing this procedure at the Leipzig Heart Center. Our findings might also have significant implications for catheter-based radiofrequency ablation procedures. Further research is required to develop safer ablation technology. Potential areas of assessment include different modes of radiofrequency application (eg, bipolar energy application) or different energy sources for ablation (eg, cryoablation and laser ablation). Until safer methods of radiofrequency ablation are developed, we currently recommend against the use of this technique in patients undergoing cardiac surgery.

References

1. Grubb NR, Furniss S. Science, medicine, and the future: radiofrequency ablation for atrial fibrillation. *BMJ.* 2001;322:777-80.
2. Patwardhan AM, Dave HH, Tamhane AA, et al. Intraoperative radiofrequency microbipolar coagulation to replace incisions of maze III procedure for correcting atrial fibrillation in patients with rheumatic valvular disease. *Eur J Cardiothorac Surg.* 1997;12:627-33.
3. Sie HT, Beukema WP, Misier AR, et al. Radiofrequency modified maze in patients with atrial fibrillation undergoing concomitant valve surgery. *J Thorac Cardiovasc Surg.* 2001;122:212-5.
4. Mohr FW, Fabricius A, Falk V, et al. Curative treatment of atrial fibrillation with intraoperative radiofrequency ablation: short-term and midterm results. *J Thorac Cardiovasc Surg.* 2002;123:919-27
5. Robbins IM, Colvin EV, Doyle TP, et al. Pulmonary vein stenosis after catheter ablation of atrial fibrillation. *Circulation.* 1998;98:1769-75.

6. Mohr FW, Autschbach R, Kottkamp H. Antiarrhythmic surgery for treatment of atrial fibrillation—new concepts. *Thorac Cardiovasc Surg.* 1999;47:365-9.
7. Kottkamp H, Hindricks G, Hammel D, et al. Intraoperative radiofrequency ablation of chronic atrial fibrillation: a left atrial curative approach by elimination of anatomic "anchor" reentrant circuits. *J Cardiovasc Electrophysiol.* 1999;10:772-80.
8. Kottkamp H, Hindricks G. Curative treatment of atrial fibrillation 2000: percutaneous catheter ablation techniques and intraoperative ablation with minimally invasive techniques. *Herzschr Elektrophys.* 2000;11(suppl II):II63-8.
9. Gillinov M, Pettersson G, Rice TW. Esophageal injury during radiofrequency ablation of atrial fibrillation. *J Thorac Cardiovasc Surg.* 2001;122:1239-40.
10. Van Oppell U, Rauch T, Hindricks G, et al. Effectiveness of two radiofrequency ablation systems in atrial tissue. *Eur J Cardiothorac Surg.* 2001;20:956–60.
11. Sueda T, Imai K, Ishii O, Orihashi K, Watari M, Okada K. Efficacy of pulmonary vein isolation for the elimination of chronic atrial fibrillation in cardiac valvular surgery. *Ann Thorac Surg.* 2001;71:1189-93.
12. Sueda T, Nagata H, Orihashi K, et al. Efficacy of a simple left atrial procedure for chronic atrial fibrillation in mitral valve operations. *Ann Thorac Surg.* 1997;63:1070-5.
13. Edmunds LH Jr, Clark RE, Cohn LH, Grunkemeier GL, Miller DC, Weisel RD. Guidelines for reporting morbidity and mortality after cardiac valvular operations. The American Association for Thoracic Surgery, Ad Hoc Liason Committee for Standardizing Definitions of Prosthetic Heart Valve Morbidity. *Ann Thorac Surg.* 1996;62:932-5.
14. Walther T, Falk V, Walther C, et al. Combined stentless mitral valve implantation and radiofrequency ablation. *Ann Thorac Surg.* 2000;70:1080-2.
15. Melo JQ, Neves J, Adragao P, et al. When and how to report results of surgery on atrial fibrillation. *Eur J Cardiothorac Surg.* 1997;12:739-45.
16. Massey SR, Pitsis A, Mehta D, Callaway M. Oesophageal perforation following perioperative transoesophageal echocardiography. *Br J Anaesth.* 2000;84:643-6.
17. Reidenbach H-D. Hochfrequenz- und Lasertechnik in der Medizin. Grundlagen und Anwendungen hochfrequenter elektromagnetischer Energie für therapeutische Wärme. Berlin: Springer-Verlag; 1983.